

## TITLE OF THE INVENTION

Lubricating Oil Composition for Transmissions

## BACKGROUND OF THE INVENTION

## Field of the Invention

This invention relates to lubricating oil compositions for transmissions, and more particularly to such lubricating oil compositions which are excellent in fuel consumption efficiency and extreme pressure properties and capable of providing gear and clutches with sufficient durabilities such that the long lasting gear change characteristics can be obtained.

## Description of the Prior Art

In recent years, for the purpose of reducing the amount of carbon dioxide emission with the background of environmental issues, it becomes an urgent matter to improve the fuel economy of automobiles, resulting in a strong demand has been urged and resulted in a strong demand for automatic transmissions which are contributive to the improvement of fuel efficiency. There is one method of making an automatic transmission contributive to the improvement of fuel efficiency in which method to lower the viscosity of an automatic transmission fluid (ATF). An automatic transmission is constituted by a torque converter, a wet clutch, a

gear bearing mechanism, and a hydraulic control mechanism and will be contributive to the improvement of fuel efficiency using an ATF with a lower viscosity which can reduce the stirring resistance in the torque converter and the oil pump.

However, it is known that a low viscosity ATF reduces the durabilities of gears determining the transmission ratios and shift clutches, leading to the poor durability of the gear change characteristics. Lowering the viscosity of an ATF reduces its extreme pressure properties and thus causes the gears to be seized, resulting in malfunctioning of the automatic transmission. The selection of gears determining transmission ratios is effected by allowing some of the wet clutches to be coupled and allowing the other to be idled. However, since a low viscosity ATF reduces the durability of wet clutches, a dynamic friction coefficient necessary to couple the clutches is not generated, resulting in a possibility that the gear change may not work. Therefore, even though an ATF is lowered in viscosity, it must be capable of maintaining the durabilities of gears and wet clutches.

As one example of the conventional transmission oil compositions, there is known one disclosed in Japanese Patent Laid-Open Publication No. 1-271494 which comprises a specific amount of a base oil containing an  $\alpha$ -olefin oligomer and a petroleum-based

lubricant fraction and a specific amount of a polymethacrylate with a specific number-average molecular weight and has a kinematic viscosity of 7 cSt or greater at 140 °C. Japanese Patent Laid-Open Publication No. 8-209174 discloses a power transmitting fluid whose main purpose is to improve the performance of a torque converter clutch in a slip mode and which comprises a base oil containing a hydrogenated mineral oil with a specific viscosity and a hydrogenated poly- $\alpha$ -olefin oligomer with a specific viscosity, an acrylic viscosity improver, and other additive components and has a viscosity of at least 6.8 cSt at 100 °C after 40 cycles in the FISST of ASTM D-5275. However, these compositions each have a high viscosity while automobile transmission oils currently available on the market have generally a viscosity of from 7 - 9 mm<sup>2</sup>/s at 100 °C. Currently, there is no commercially available transmission oil having a viscosity lower than those on the market because it is difficult to lower the viscosity while maintaining the durabilities of gears and wet clutches.

In view of the above-described circumstances, a general object of the present invention is to provide a low viscosity transmission lubricating oil composition which is excellent in fuel efficiency and provides gears and wet clutches with sufficient durabilities such that the long lasting gear change

characteristics can be obtained.

#### SUMMARY OF THE INVENTION

According to the present invention, there is provided a lubricating oil composition for transmissions which comprises a mineral lubricating oil having a kinematic viscosity of from 2.3 to 3.4 mm<sup>2</sup>/s and a %Cp of 70 or higher defined by ASTM D 3238 (hereinafter referred to as "Component (A)"), as a base oil, a phosphorus compound (hereinafter referred to as "Component (B)") in an amount of from 0.025 to 0.05 percent by mass in terms of phosphorus based on the composition, and a viscosity index improver (hereinafter referred to as "Component (C)") in such an amount that the composition has a kinematic viscosity of from 5.0 to 6.0 mm<sup>2</sup>/s, sulfur being contained in an amount of 0.15 percent by mass or less in said composition..

#### DETAILED DESCRIPTION OF THE INVENTION

The lubricating oil composition for transmissions (hereinafter may be referred to as "lubricating oil composition" or "lubricating oil") of the present invention will be described in detail below.

Component (A) for use in the present invention comprises a mineral oil having a kinematic viscosity of from 2.3 to 3.4 mm<sup>2</sup>/s and a %Cp of 70 or higher defined by ASTM D 3238.

Due to the use of Component (A) comprising a

mineral base oil meeting the above-described requirements, blended with Components (B) and (C) such that the sulfur content is adjusted to a specific amount, the resulting composition synergistically exhibits excellent fuel efficiency and extreme pressure properties and provides gears and wet clutches used under severe conditions with excellent durabilities.

The upper limit kinematic viscosity of the mineral oil is  $3.4 \text{ mm}^2/\text{s}$ , preferably  $3.3 \text{ mm}^2/\text{s}$  at  $100^\circ\text{C}$ , while the lower limit is  $2.3 \text{ mm}^2/\text{s}$ , preferably  $2.5 \text{ mm}^2/\text{s}$  at  $100^\circ\text{C}$ . A kinematic viscosity in excess of  $3.4 \text{ mm}^2/\text{s}$  at  $100^\circ\text{C}$  is not preferred because it causes the increase of friction loss at the sites to be lubricated due to the increased fluid resistance, while a kinematic viscosity less than  $2.3 \text{ mm}^2/\text{s}$  at  $100^\circ\text{C}$  is not also preferred because the resulting composition would be poor in lubricity due to insufficient oil film formation at the sites to be lubricated and encounters the evaporation loss of the base oil.

The  $\%C_p$  of the mineral base oil defined by ASTM D 3238 used in the present invention is preferably 71 or higher, more preferably 72 or higher, further more preferably 73 or higher, and still further preferably 74 or higher and is preferably 90 or lower, more preferably 85 or lower, and particularly preferably 82 or lower with the objective of obtaining an excellent solubility to additives. The  $\%C_p$  defined by ASTM D 3238

used herein refers to a percentage of paraffin carbon number to the total carbon number obtained by the ring analysis stipulated by this method.

No particular limitation is imposed on the viscosity index of mineral base oils used for Component (A). However, the viscosity index is preferably 50 or higher, more preferably 80 or higher, and further more preferably 100 or higher and is preferably 140 or lower and more preferably 130 or lower with the objective of more excellent low temperature properties. The use of a mineral base oil having a viscosity index of 50 or higher makes it possible to obtain a lubricating oil composition having the capabilities of both oil film formation and flow resistance reduction.

No particular limitation is imposed on the pour point of mineral base oils used for Component (A) as well. However, the pour point is preferably 0 °C or lower, more preferably -5 °C or lower, and particularly preferably -10 °C. The use of a mineral base oil having a pour point of 0 °C or lower makes it possible to obtain a lubricating oil composition which is less preventive of the work of a machine at low temperatures.

No particular limitation is imposed on the method of producing mineral base oils used for Component (A). For example, the mineral base oils may be paraffinic and naphthenic oils which can be obtained by subjecting a lubricating oil fraction produced by atmospheric- or

vacuum- distilling a crude oil, to one or more refining processes such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, hydrorefining, sulfuric acid treating, and clay treatment. These base oils may be used singly or in combination mixed in an arbitrary proportion.

More preferred methods of producing mineral base oils used in the present invention are as follows.

For example, the mineral base oils can be obtained by refining the starting oil or lubricant fractions recovered therefrom through usual refining processes and then recovering the lubricant fractions. The starting oil may be (1) distillate oils resulting from the atmospheric distillation of a paraffin based crude oil and/or of a mixed base crude oil; (2) vacuum distillate oils (WVGO) resulting from the vacuum distillation of the topped crude of a paraffin based crude oil and/or of a mixed base crude oil; (3) oils resulting from mild hydrocracking (MHC) of oils (1) and/or (2); (4) mixed oils of two or more selected from oils (1), (2), and (3); (5) deasphalted oils (DAO) of oils (1) to (4); (6) oils resulting from mild hydrocracking of oils (5); and (7) mixed oils of two or more selected from oils (1) to (6).

There is no restriction to the usual refining processes mentioned above which, therefore, may be any

of the refining methods used upon production of lubricant base oils. Specific examples of such refining methods are (a) hydro-refining such as hydrocracking and hydro-finishing; (b) solvent refining such as furfural extraction; (c) dewaxing such as solvent dewaxing and catalytic dewaxing; (d) clay treatment with acid clay or active clay; and (e) acid or alkali chemical refining such as sulfuric acid washing and caustic soda washing. In the present invention, one or more of these methods may be used in any combination in any order.

Particularly preferred mineral oils used in the present invention are starting oils selected from the above described (1) to (7); products obtained by hydrocracking lubricant fractions recovered from the starting oils; or components obtained by subjecting lubricant fractions recovered from the products to a dewaxing treatment such as solvent- or catalytic-dewaxing and then solvent-refining the resulting product, alternatively followed by a dewaxing treatment such as solvent- or catalytic-dewaxing.

Component (A) used in the present invention may be a mixture of two or more mineral oils obtained by any of the above-described refining methods or a single kind of refined mineral oil. However, in either case, base oils used for Component (A) must meet the



requirements that the kinematic viscosity is from 2.3 to 3.4 mm<sup>2</sup>/s at 100 °C and the %C<sub>p</sub> defined by ASTM D 3238 is 70 or higher. In other words, as long as the requirements are met, any kind of mineral oil can be used as Component (A).

The mineral base oil used in the present invention may contain a small amount of synthetic oils such as poly- $\alpha$ -olefins and ester-based synthetic oils. However, in the lubricating oil composition of the present invention, Component (A) is contained in an amount of preferably at least 50 percent by mass, more preferably 60 percent by mass or more, further more preferably 75 percent by mass or more, and still further more preferably 80 percent by mass or more of the base oil.

Component (B) contained in the lubricating oil composition of the present invention is a phosphorus compound.

The content of Component (B) is from 0.025 to 0.05 percent by mass, preferably from 0.025 to 0.04 percent by mass, and particularly preferably from 0.03 to 0.035 in terms of phosphorus based on the total mass of the lubricating oil composition with the objective of imparting thereto excellent extreme pressure properties. Contents less than 0.025 percent by mass in terms of phosphorus are less effective to extreme pressure properties, while contents in excess of 0.05

percent by mass cause the deterioration of oxidation stability of the resulting composition and of durability of resin materials such as nylon.

Examples of phosphorus compound for Component (B) are zinc alkyldithiophosphate, phosphoric acid, phosphorous acid, monophosphates, diphosphates, triphosphates, monophosphites, diphosphites, triphosphites, salts of phosphates and phosphites, thiophosphates, thiophosphites and esters thereof, and mixtures thereof. Among these components (Component (B)), those other than phosphoric acid, thiophosphates, phosphorus acid, and thiophosphites are compounds containing a hydrocarbon group having 2 to 30, preferably 3 to 20 carbon atoms.

Examples of hydrocarbon groups having 2 to 30 carbon atoms are alkyl, cycloalkyl, alkylcycloalkyl, aryl, alkylaryl, and arylalkyl groups.

Examples of alkyl groups are ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, and octadecyl groups, all of which may be straight-chain or branched.

Examples of cycloalkyl groups are those having 5 to 7 carbon atoms, such as cyclopentyl, cyclohexyl, and cycloheptyl groups.

Examples of alkylcycloalkyl groups are those having 6 to 11 carbon atoms, of which the cycloalkyl

group may possess an alkyl substituent at any position, such as methylcyclopentyl, dimethylcyclopentyl, methylethylcyclopentyl, diethylcyclopentyl, methylcyclohexyl, dimethylcyclohexyl, methylethylcyclohexyl, diethylcyclohexyl, methylcycloheptyl, dimethylcycloheptyl, methylethylcycloheptyl and diethylcycloheptyl groups.

Examples of alkenyl groups are butenyl, pentenyl, hexenyl, heptenyl, octenyl, nonenyl, decenyl, undecenyl, dodecenyl, tridecenyl, tetradecenyl, pentadecenyl, hexadecenyl, heptadecenyl and octadecenyl groups, all of which may be straight-chain or branched and the position of which the double bond may vary.

Examples of aryl groups are phenyl and naphthyl. Examples of alkylaryl groups are those having 7 to 18 carbon atoms, such as tolyl, xylyl, ethylphenyl, propylphenyl, butylphenyl, pentylphenyl, hexylphenyl, heptylphenyl, octylphenyl, nonylphenyl, decylphenyl, undecylphenyl, and dodecylphenyl groups, all of which the alkyl group may be straight-chain or branched and may bond to any position of the aryl group.

Examples of arylalkyl groups are those having 7 to 12 carbon atoms, such as benzyl, phenylethyl, phenylpropyl, phenylbutyl, phenylpentyl and phenylhexyl groups, all of which may be straight-chain or branched.

Preferred compounds as Component (B) are phosphoric acid; phosphorus acid; zinc alkyl dithiophosphates, of which the alkyl group may be straight-chain or branched, such as zinc dipropyldithiophosphate, zinc dibutyldithiophosphate, zinc dipentyldithiophosphate, zinc dihexyldithiophosphate, zinc diheptyldithiophosphate, and zinc dioctyldithiophosphate; monoalkyl phosphates, of which the alkyl group may be straight-chain or branched, such as monopropyl phosphate, monobutyl phosphate, monopentyl phosphate, monohexyl phosphate, monoheptyl phosphate and mono-octyl phosphate; mono(alkyl)aryl phosphates such as monophenyl phosphate and monocresyl phosphate; dialkyl phosphates, of which the alkyl group may be straight-chain or branched, such as dipropyl phosphate, dibutyl phosphate, dipentyl phosphate, dihexyl phosphate, diheptyl phosphate and dioctyl phosphate; di(alkyl)aryl phosphates such as diphenyl phosphate and dicresyl phosphate; trialkyl phosphates, of which the alkyl group may be straight-chain or branched, such as tripropyl phosphate, tributyl phosphate, tripentyl phosphate, trihexyl phosphate, triheptyl phosphate and trioctyl phosphate; tri(alkyl)aryl phosphates such as triphenyl phosphate and tricresyl phosphate; monoalkyl phosphites, of which the alkyl group may be straight-chain or branched, such as monopropyl

phosphite, monobutyl phosphite, monopentyl phosphite, monohexyl phosphite, monoheptyl phosphite and monooctyl phosphite; mono(alkyl)aryl phosphites such as monophenyl phosphite and monocresyl phosphite; dialkyl phosphites, of which the alkyl group may be straight-chain or branched, such as dipropyl phosphite, dibutyl phosphite, dipentyl phosphite, dihexyl phosphite, diheptyl phosphite and dioctyl phosphite; di(alkyl)aryl phosphites such as diphenyl phosphite and dicresyl phosphite; trialkyl phosphites, of which the alkyl group may be straight-chain or branched, such as tripropyl phosphite, tributyl phosphite, tripentyl phosphite, trihexyl phosphite, triheptyl phosphite and trioctyl phosphite; tri(alkyl)aryl phosphites, of which the alkyl group may be straight-chain or branched, such as triphenyl phosphite and tricresyl phosphite; and mixtures thereof.

Specific examples of salts of phosphites and phosphates are those obtained by allowing a monophosphate, a diphosphate, a monophosphite, or a diphosphite to react with a nitrogen-containing compound such as ammonia or an amine compound having in its molecules only hydrocarbon or hydroxyl-containing groups having 1 to 8 carbon atoms so as to neutralize the whole or part of the remaining acid hydrogen.

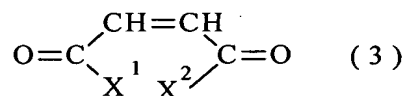
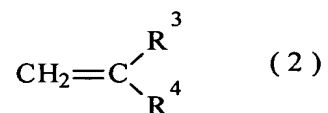
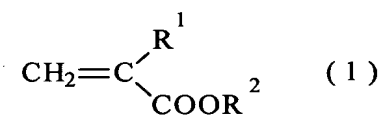
Specific examples of the nitrogen-containing

compound are ammonia; alkylamines, of which the alkyl group may be straight-chain or branched, such as monomethylamine, monoethylamine, monopropylamine, monobutylamine, monopentylamine, monohexylamine, monoheptylamine, monooctylamine, dimethylamine, methylethylamine, diethylamine, methylpropylamine, ethylpropylamine, dipropylamine, methylbutylamine, ethylbutylamine, propylbutylamine, dibutylamine, dipentylamine, dihexylamine, diheptylamine and dioctylamine; alkanolamines, of which the alkanol group may be straight-chain or branched, such as monomethanolamine, monoethanolamine, monopropanolamine, monobutanolamine, monopentanolamine, monohexanolamine, monoheptanolamine, monooctanolamine, monononanolamine, dimethanolamine, methanolethanolamine, diethanolamine, methanolpropanolamine, ethanolpropanolamine, dipropanolamine, methanolbutanolamine, ethanolbutanolamine, propanolbutanolamine, dibutanolamine, dipentanolamine, dihexanolamine, diheptanolamine and dioctanolamine; and mixtures thereof. One or more of these Components (B) may be blended arbitrarily.

Phosphites and/or thiophosphites are preferably used as Component (B) of the lubricating oil composition of the present invention.

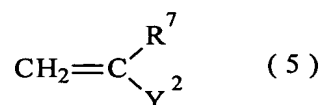
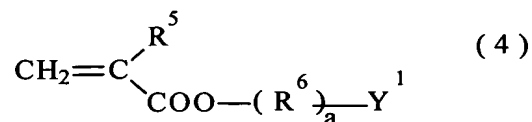
Viscosity index improvers, i.e., Component (C) are non-dispersion type and/or dispersion type viscosity index improvers.

Specific examples of the non-dispersion type-viscosity index improvers are copolymers of one or more monomers selected from the group consisting of compounds represented by formulas (1), (2) and (3) below, and hydrides of the copolymers:



Specific examples of dispersion type-viscosity index improvers are copolymers of two or more monomers selected from the group consisting of compounds represented by formulas (4) and (5) below; ones obtained by introducing an oxygen-containing group into hydrides of the copolymers; copolymers of one or more monomers selected from the group consisting of compounds represented by formulas (1), (2) and (3) above with one or more monomers selected from the group consisting of compounds represented by formulas (4) and

(5) below; and hydrides of the copolymers:



In formula (1) above,  $\text{R}^1$  is hydrogen or methyl, and  $\text{R}^2$  is an alkyl group having 1 to 18 carbon atoms.

Specific examples of alkyl groups having 1 to 18 carbon atoms for  $\text{R}^2$  are alkyl groups, which may be straight-chain or branched, such as methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, and octadecyl groups.

In formula (2) above,  $\text{R}^3$  is hydrogen or methyl, and  $\text{R}^4$  is a hydrocarbon group having 1 to 12 carbon atoms.

Specific examples of hydrocarbon groups having 1 to 12 carbon atoms for  $\text{R}^4$  are alkyl groups, which may be straight-chain or branched, such as methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, and dodecyl groups; alkenyl groups, which may be straight-chain or branched and the position of which the double bond may vary, such as butenyl, pentenyl, hexenyl, heptenyl, octenyl, nonenyl, decenyl, undecenyl, and dodecenyl groups; cycloalkyl



groups having 5 to 7 carbon atoms, such as cyclopentyl, cyclohexyl, and cycloheptyl groups; alkylcycloalkyl groups, of which the alkyl group may be bonded to any position of the cycloalkyl group, having 6 to 11 carbon atoms, such as methylcyclopentyl, dimethylcyclopentyl, methylethylcyclopentyl, diethylcyclopentyl, methylcyclohexyl, dimethylcyclohexyl, methylethylcyclohexyl, diethylcyclohexyl, methylcycloheptyl, dimethylcycloheptyl, methylethylcycloheptyl, and diethylcycloheptyl groups; aryl groups such as phenyl and naphthyl groups; alkylaryl groups, of which the alkyl group may be straight-chain or branched and bond to any position of the aryl group, having 7 to 12 carbon groups, such as tolyl, xylyl, ethylphenyl, propylphenyl, butylphenyl, pentylphenyl, and hexylphenyl groups; and arylalkyl groups, of which the alkyl group may be straight-chain or branched, having 7 to 12 carbon atoms, such as benzyl, phenylethyl, phenylpropyl, phenylbutyl, phenylpentyl, and phenylhexyl groups.

In formula (3) above,  $X^1$  and  $X^2$  are each independently hydrogen, an alkoxy having 1 to 18 carbon atoms represented by the formula  $-OR^{10}$  wherein  $R^{10}$  is an alkyl group having 1 to 18 carbon atoms, or a monoalkylamine having 1 to 18 carbon atoms represented by the formula  $-NHR^{11}$  wherein  $R^{11}$  is an alkyl group having 1 to 18 carbon atoms.

In formula (4) above,  $R^5$  is hydrogen or methyl,  $R^6$  is an alkylene group having 1 to 18 carbon atoms,  $Y^1$  is an amine residue or heterocyclic residue having 1 or 2 nitrogen and 0 to 2 oxygen, and  $a$  is an integer of 0 or 1.

Specific examples of alkylene groups having 1 to 18 carbon atoms for  $R^6$  are ethylene, propylene, butylene, pentylene, hexylene, heptylene, octylene, nonylene, decylene, undecylene, dodecylene, tridecylene, tetradecylene, pentadecylene, hexadecylene, heptadecylene, and octadecylene groups, all of which may be straight-chain or branched.

Specific examples of groups represented by  $Y^1$  are dimethylamino, diethylamino, dipropylamino, dibutylamino, anilino, toluidino, xylidino, acetylamino, benzoilamino, morpholino, pyrrolyl, pyrrolino, pyridyl, methylpyridyl, pyrrolidinyl, piperidinyl, quinonyl, pyrrolidonyl, pyrrolidono, imidazolino, and pyrazino groups.

In formula (5),  $R^7$  is hydrogen or methyl, and  $Y^2$  is an amino- or heterocyclic- residue having 1 or 2 nitrogen and 0 to 2 oxygen.

Specific examples of groups represented by  $Y^2$  are dimethylamino, diethylamino, dipropylamino, dibutylamino, anilino, toluidino, xylidino, acetylamino, benzoilamino, morpholino, pyrrolyl, pyrrolino, pyridyl, methylpyridyl, pyrrolidinyl,

piperidinyl, quinonyl, pyrrolidonyl, pyrrolidono, imidazolino, and pyrazino groups.

Preferred one or more monomers selected from compounds of formulas (1) - (3) above are alkylacrylates having 1 to 18 carbon atoms, alkylmethacrylates having 1 to 18 carbon atoms, olefins having 2 to 20 carbon atoms, styrene, methylstyrene, maleic anhydride ester, maleic anhydride amide, and mixtures thereof.

Preferred one or more monomers selected from compounds of formulas (4) and (5) are dimethylaminomethylmethacrylate, diethylaminomethylmethacrylate, dimethylaminoethylmethacrylate, diethylaminoethylmethacrylate, 2-methyl-5-vinylpyridine, morpholinomethylmethacrylate, morpholinoethylmethacrylate, N-vinylpyrrolidone, and mixtures thereof.

When one or more monomers selected from compounds of formulas (1) - (3) is copolymerized with one or more monomers selected from compounds of formulas (4) and (5), the molar ratio of the former to the latter is within the range of 80 : 20 to 95 : 5. Although no particular limitation is imposed on the copolymerization method, such copolymers are generally obtained by radical-solution polymerization of the

former with the latter in the presence of a polymerization initiator such as benzoyl peroxide.

Specific examples of the viscosity index improvers are non-dispersion type- and dispersion type- polymethacrylates, non-dispersion type- and dispersion type- ethylene- $\alpha$ -olefin copolymers and hydrides thereof, polyisobutylene and hydrides thereof, styrene-diene hydrogenated copolymers, styrene-maleic anhydrides copolymers, and polyalkylstyrene.

The molecular weight of Component (C) is preferably selected in view of shear stability. Specifically, it is desired that the dispersion type and non-dispersion type- polymethacrylates have a number-average molecular weight of 5,000 to 150,000, preferably 5,000 to 35,000. It is also desired that the polyisobutylenes and hydrides thereof have a number-average molecular weight of 800 to 5,000, preferably 2,000 to 4,000. Polyisobutylenes and hydrides thereof having a number-average molecular weight of less than 800 would be poor in thickening properties, while those having a number-average molecular weight in excess of 5,000 would deteriorate the shear stability and low-temperature flowability of the resulting lubricating oil composition.

The lubricating oil composition of the present invention contains Component (C) in such an amount that the kinematic viscosity of the composition is made to

from 5.0 to 6.0 mm<sup>2</sup>/s at 100°C. One or more compounds selected from these viscosity index improvers may be blended in an arbitrary amount. A lubricating oil composition with a kinematic viscosity less than 5.0 mm<sup>2</sup>/s at 100 °C is deteriorated in wear resistance, while one with a kinematic viscosity in excess of 6.0 mm<sup>2</sup>/s at 100 °C can not obtain a fuel efficiency as intended by the present invention. As long as the lubricating oil composition of the present invention has a kinematic viscosity at 100 °C within the above-described range, the content of Component (C) is arbitrarily selected. However, the content is generally from 0.1 to 20 percent by mass, based on the total mass of the composition.

The upper limit sulfur content in the lubricating oil composition is 0.15 percent by mass, preferably 0.14 percent by mass, based on the total mass of the composition. A lubricating oil composition with a sulfur content in excess of 0.15 percent by mass reduces the durability of wet clutches. No particular limitation is imposed on the lower limit of sulfur content. However, the lower limit is preferably 0.02 percent by mass, more preferably 0.03 percent by mass, and particularly preferably 0.05 percent by mass with the objectives of producing a composition which is excellent in metal fatigue life and high in seizing load. Examples of compounds containing sulfur are base

oils containing sulfur contained in Component (A), phosphorus compounds containing sulfur contained in Component (B), compounds generally used in ATFs such as thiazole compounds, thiadiazole compounds, dithiocarbamate compounds, molybdenum dithiocarbamate compounds, dihydrocarbylpolysulfide compounds, sulfurized ester compounds, alkaline earth metal sulfonates, and alkaline earth metal phenates, or sulfuric compounds contained in diluent oils (light lubricant base oil or the like) for additives.

In the present invention, a lubricating oil composition of the present invention which is excellent in fuel efficiency and extreme pressure properties for gears and capable of providing wet clutches with durability can be obtained by blending Component (A) as the base oil and Components (B) and (C) in specific amounts such that the kinematic viscosity of the resulting composition is made to from 5.0 to 6.0 mm<sup>2</sup>/s at 100 °C and the sulfur content is made to 0.15 percent by mass or less, based on the total mass of the composition. In order to further enhance the properties, there may be added ashless dispersants such as succinimides, metallic detergents such as calcium sulfonates, extreme pressure additives other than Component (B), friction modifiers, phenol- or amine-based oxidation inhibitors, rust inhibitors, corrosion inhibitors such as thiadiazoles, pour-point

depressants, rubber swelling agents, antifoamers, and coloring agents. These additives may be used singly or in combination. The amounts of these additives based on the total mass of the composition are from 0.1 to 10 percent by mass for ashless dispersants and metallic detergents, from 0.01 to 5 percent by mass for extreme pressure additives, friction modifiers, oxidation inhibitors, rust inhibitors, corrosion inhibitors, pour-point depressants, and rubber swelling agents, and from 0.0001 to 0.05 percent by mass for antifoamers and coloring agents.

The present invention will be further described in the following examples, but the present invention should not be construed as being limited thereto.

#### Examples

##### Examples 1 to 6 and Comparative Examples 1 to 5

Various lubricating oil compositions were prepared in accordance with the formulations shown in Tables 1 (Examples) and 2 (Comparative Examples). Various additives were added in amounts based on the total mass of the composition.

Each of the resulting lubricating oil compositions was evaluated by (1) gear-shifting property test and (2) extreme pressure test, and the results were also shown in Tables 1 and 2.

##### (1) Gear-shift property test

Each of the compositions was subjected to a test

for evaluating its friction property for wet clutches.

The friction property test for wet clutches was conducted in accordance with JASO M348-95 "Test Method for Friction Property of Automatic Transmission Fluids" using an SAE No. 2 test machine under the following conditions thereby evaluating the durability of the shifting properties of a clutch.

(Test Conditions)

Fluid Temperature : 120 °C

Number of Revolutions : 5,000 rpm

Moment of Inertia : 0.343 kg·m

Pushing Load : 0.785 kPa

Number of Tests : 2500

Pressing Time : 4 seconds

The rest of the conditions were determined in accordance with JASO M348-95.

In this test, only the dynamic friction test was conducted wherein after the clutch was rotated at the constant speed of 5,000 rpm without load using flywheels with a moment of inertia of 0.343 kg·m, the clutch was stopped by applying a pressure thereto. The friction coefficient was calculated from the torque generated when the number of revolutions of the clutch was reduced to 1,800 rpm and was defied as the dynamic friction coefficient.

(Evaluation criterion)

2,500 cycles of the dynamic friction test was



conducted for each of the compositions such that the durability of shifting properties thereof was evaluated by the difference between the dynamic friction coefficient after 500 cycles and that after 2,500 cycles. When the difference was within 0.02, the composition was evaluated to be excellent in the durability.

## (2) Extreme Pressure Property Test

The extreme pressure property test was conducted using a Shell four-ball testing machine in accordance with ASTM D 2783 "Standard Test Method for Measurement of Extreme-Pressure Property of Lubricating Fluids (Four-Ball Method)". One steel ball was fixed on the rotating axis and three steel balls were placed in the vessel such that all the four balls contact with each other. The vessel was filled with a sample oil. A load was applied to the three balls by pressing the ball on the rotation axis while the axis was held stationary. Thereafter, the rotation axis was rotated at a speed of  $1,760 \pm 40$  rpm for 10 seconds and the load was increased until welding occurs so as to obtain the last non-seizure load which is the last load at which the measured scar diameter is not more than 105 percent above the compensation scar diameter at the load. The higher the last non-seizure load, the better the extreme pressure properties of the sample.

**Tabl 1**

		Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
<b>Component (A)</b>							
Base Oil 1 <sup>1)</sup>	mass%	70.1	40.0	63.6	29.7	63.6	63.6
Base Oil 2 <sup>2)</sup>	mass%	13.4	46.9	12.7	21.2	12.7	12.7
Base Oil 3 <sup>3)</sup>	mass%	0.0	0.0	8.5	17.0	8.5	8.5
Base Oil 4 <sup>4)</sup>	mass%	0.0	0.0	0.0	17.0	0.0	0.0
Kinematic Viscosity of Component (A) (100°C)	mm <sup>2</sup> /s	2.8	3.3	3	3	3	3
%Cp of Component (A)		74	76	73	71	73	73
<b>Component (B)</b>							
Phosphorus Additive 1 <sup>5)</sup>	mass%	0.2	0.2	0.2	0.2	0.15	0.10
Phosphorus Additive 2 <sup>6)</sup>	mass%					0.17	0.34
Phosphorus Content in Component (B)	mass%	0.03	0.03	0.03	0.03	0.03	0.03
Sulfur Content in Component (B)	mass%	0.00	0.00	0.00	0.00	0.026	0.052
<b>Component (C)</b>							
Viscosity Index Improver <sup>7)</sup>	mass%	12	8.6	10.7	10.7	10.7	10.7
<b>Other Additives</b>							
Ashless Dispersant <sup>8)</sup>	mass%	3.0	3.0	3.0	3.0	3.0	3.0
Ca-based Detergent <sup>9)</sup>	mass%	0.1	0.1	0.1	0.1	0.1	0.1
Friction Modifier <sup>10)</sup>	mass%	0.1	0.1	0.1	0.1	0.1	0.1
Oxidation Inhibitor 1 <sup>11)</sup>	mass%	0.5	0.5	0.5	0.5	0.5	0.5
Oxidation Inhibitor 2 <sup>12)</sup>	mass%	0.5	0.5	0.5	0.5	0.5	0.5
Corrosion Inhibitor <sup>13)</sup>	mass%	0.1	0.1	0.1	0.1	0.1	0.1
Antifoamer <sup>14)</sup>	mass%	0.002	0.002	0.002	0.002	0.002	0.002
Kinematic Viscosity of Composition (100°C)	mm <sup>2</sup> /s	5.5	5.5	5.5	5.5	5.5	5.5
Sulfur Content in Composition	mass%	0.07	0.07	0.08	0.13	0.11	0.13
<b>SAE No.2 Test</b>							
Friction Coefficient after 500 cycles		0.12	0.12	0.12	0.12	0.12	0.12
Friction Coefficient after 2,500 cycles		0.11	0.11	0.11	0.11	0.11	0.11
Last Non-Seizure Load	N	618	618	618	618	618	785

1) Hydrogenated Refined Base Oil (viscosity index 105, %Cp 73)

2) Hydrogenated Refined Base Oil (viscosity index 125, %Cp 79)

3) Solvent Refined Base Oil (viscosity index 95, %Cp 67)

4) Solvent Refined Base Oil (viscosity index 95, %Cp 61)

5) Phosphite (phosphorus content 16.4mass%)

6) Trithiophosphite (phosphorus content 4.9mass%, sulfur content 15.2mass%)

7) Non Dispersion Type Polymethacrylate (weight average molecular weight 20,000)

8) Polybutenyl Succinimide (bistype)

9) Calcium Sulfonate (total acid value 300mgKOH/g)

10) Amine-based

11) Dialkyldiphenylamine

12) Bis phenol-based

13) Thiadiazole-based

14) Polydimethylsiloxane

**Tabl 2**

		Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
<b>Component (A)</b>						
Base Oil 1 <sup>1)</sup>	mass%	33.9	0.0	63.6	63.7	0.0
Base Oil 2 <sup>2)</sup>	mass%	8.5	0.0	12.7	12.7	0.0
Base Oil 3 <sup>3)</sup>	mass%	25.4	46.6	8.5	8.5	0.0
Base Oil 4 <sup>4)</sup>	mass%	17.0	38.2	0.0	0.0	78.4
Kinematic Viscosity of Component (A) (100°C)	mm <sup>2</sup> /s	3	3	3	3	2.1
%Cp of Component (A)		69	64	73	73	61
<b>Component (B)</b>						
Phosphorus Additive 1 <sup>5)</sup>	mass%	0.2	0.2	0.05	0.1	0.2
Phosphorus Additive 2 <sup>6)</sup>	mass%			0.51		
Phosphorus Content in Component (B)	mass%	0.03	0.03	0.03	0.02	0.03
Sulfur Content in Component (B)	mass%	0.00	0.00	0.078	0.00	0.00
<b>Component (C)</b>						
Viscosity Index Improver <sup>7)</sup>	mass%	10.7	10.7	10.7	10.7	17.1
<b>Other Additives</b>						
Ashless Dispersant <sup>8)</sup>	mass%	3.0	3.0	3.0	3.0	3.0
Ca-based Detergent <sup>9)</sup>	mass%	0.1	0.1	0.1	0.1	0.1
Friction Modifier <sup>10)</sup>	mass%	0.1	0.1	0.1	0.1	0.1
Oxidation Inhibitor 1 <sup>11)</sup>	mass%	0.5	0.5	0.5	0.5	0.5
Oxidation Inhibitor 2 <sup>12)</sup>	mass%	0.5	0.5	0.5	0.5	0.5
Corrosion Inhibitor <sup>13)</sup>	mass%	0.1	0.1	0.1	0.1	0.1
Antifoamer <sup>14)</sup>	mass%	0.002	0.002	0.002	0.002	0.002
Kinematic Viscosity of Composition (100°C)	mm <sup>2</sup> /s	5.5	5.5	5.5	5.5	5.5
Sulfur Content in Composition	mass%	0.14	0.22	0.16	0.07	0.23
<b>SAE No.2 Test</b>						
Friction Coefficient after 500 cycles		0.12	0.12	0.12	0.11	0.13
Friction Coefficient after 2,500 cycles		0.09	0.08	0.09	0.11	0.08
Last Non-Seizure Load	N	618	618	785	392	392

1) Hydrogenated Refined Base Oil (viscosity index 105, %Cp 73)

2) Hydrogenated Refined Base Oil (viscosity index 125, %Cp 79)

3) Solvent Refined Base Oil (viscosity index 95, %Cp 67)

4) Solvent Refined Base Oil (viscosity index 95, %Cp 61)

5) Phosphite (phosphorus content 16.4mass%)

6) Trithiophosphite (phosphorus content 4.9mass%, sulfur content 15.2mass%)

7) Non Dispersion Type Polymethacrylate (weight average molecular weight 20,000)

8) Polybutenyl Succinimide (bistype)

9) Calcium Sulfonate (total acid value 300mgKOH/g)

10) Amine-based

11) Dialkyldiphenylamine

12) Bis phenol-based

13) Thiadiazole-based

14) Polydimethylsiloxane

As apparent from the test results shown in Tables 1 and 2, the lubricating oil compositions according to the present invention (Examples 1 to 6) were less in the reduction of dynamic friction coefficient and high in extreme pressure properties.

Whereas, the lubricating oil composition containing a mineral base oil whose %Cp was less than 70 (Comparative Example 1) and the composition containing a mineral base oil whose %Cp was less than 70 and containing more than 0.15 percent by mass of sulfur (Comparative Example 2) were large in the reduction of dynamic friction coefficient, while the composition containing a sulfur-containing phosphorus compound and thus containing sulfur in an amount of more than 0.15 percent by mass of the composition (Comparative Example 3) was high in extreme pressure properties but large in the reduction of dynamic friction coefficient. The composition containing a phosphorus compound in an amount of less than 0.025 percent by mass in terms of phosphorus (Comparative Example 4) was significantly reduced in extreme pressure properties, while the composition whose Component (A) does not meet the requirements of the base oil kinematic viscosity and %Cp and sulfur content exceeds the range defined by the present invention (Comparative Example 5) was large in the reduction of

dynamic friction coefficient and poor in extreme pressure properties.

The lubricating oil composition of the present invention with the above described structure can not only be expected to make a transmission contributive to enhance the fuel efficiency due to its ability of reducing the stirring resistance in a torque converter or an oil pump but also provide wet clutches with a sufficient durability and obtain excellent extreme pressure properties. Therefore, the lubricating oil composition of the present invention is extremely useful as a fuel efficient type transmission oil composition which is completely different from the conventional ones.